Scenarios and challenges for feeding the world in 2050

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OECD workshop “Long-Term Scenarios
Supporting Robust Policies for Global Agriculture and Food”
Paris, 21-22 October 2010

The foresight exercise Agrimonde (introduction)

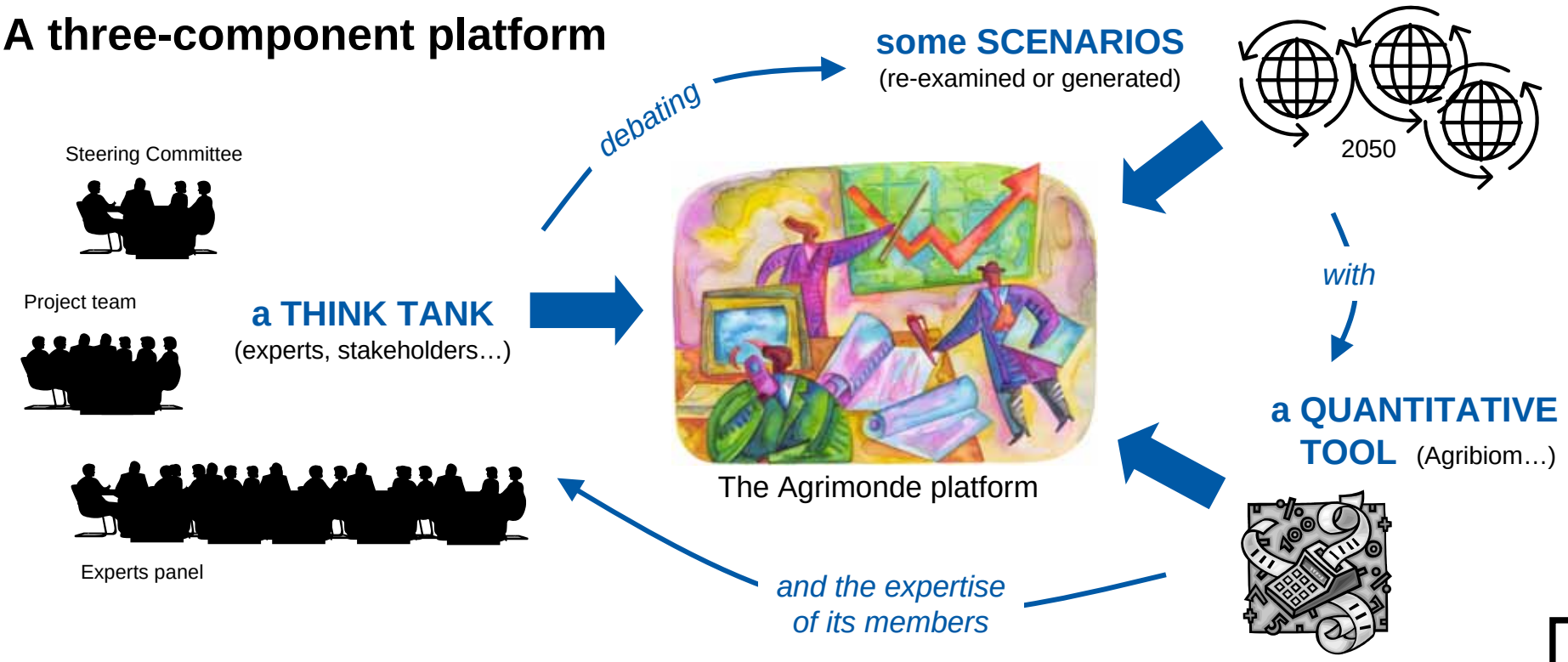
A joint INRA-CIRAD project (2006-2009 = 1st phase)

- French National Institute for Agricultural Research (www.inra.fr)
- French Agricultural Research Centre for International Development (www.cirad.fr)

Objectives

(1) to explore possible futures of food and farming systems up to 2050
(2) to design and debate orientations and strategies for INRA - CIRAD research agendas
(3) to contribute to international debates on food, agriculture and the environment

A three-component platform



Part I

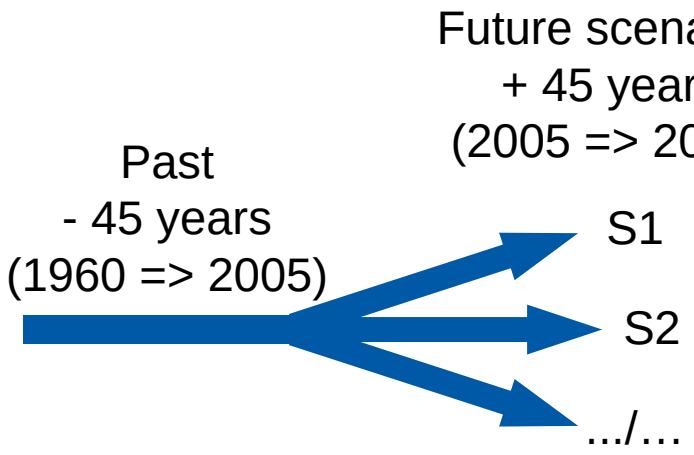
Aims & architecture of Agribiom

A quantitative tool designed for exploring
past and future world production, consumption & trade of biomasses
through (1) collective expertise & debates (such as Agrimonde)
(2) hybrid modeling works (not presented here)

❶ The ambition for Agrimonde

Having a quantitative tool for :

(1) revisiting the past,
better understand it (with new estimates, new models…)



(2) debating the future
...from scenarios description (own or external qualitative conjectures)

translated / summarized into
few quantitative parameters (populations, diets, non-food uses land uses, productivities…)

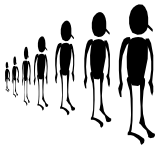
Global Consistency ?
(physical equilibrium between biomass uses & resources)

Implications ? (international trade, fossil fuel & water consumptions…)

Impact of variants ?
(populations, composition of diets…)

❷ A food balance model

Countries => World balances of food biomasses reconstituted (1961-2003, using FAO commodity balances in tons) and/or simulated (2030, 2050…)



Regional POPULATION

Population

Agricultural working population	Rural population other than farmers	Urban citizens

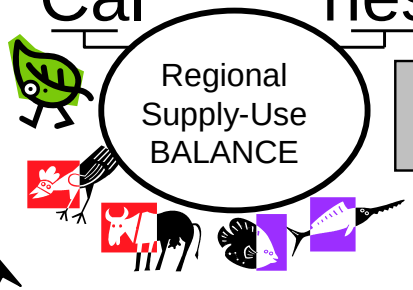
Demand

Regional CONSUMPTION

Biomass

FOOD			NON-FOOD (wood, fibres, leather, rubber, tobacco, bio-energies, bio-materials…)
from terrestrial PLANTS	from terrestrial ANIMALS	of AQUATIC origins	

Cal ries



Regional Supply-Use BALANCE

Production	Imports – Exports	Food use	Feed use	Seed use	Other use	Waste	Imports – Exports	Production

Regional PRODUCTION

	Edible	Inedible
VEGE		
MONO		
RUMI		
AQUA		
MARI		

yield

Regional LAND USE

Croplands	totally non-food	Permanent pastures	Forests	Others (mountains, deserts, cities, roads…)	Freshwater

Continental shelves

❸ The unit of account

Food CALORIES
(or equivalent for oilcakes, molasses…)

Total Calories = Carbohydrates (4 kcal/g)
+ Proteins (4 kcal/g)
+ Fat (9 kcal/g)

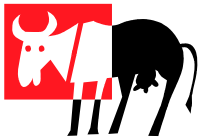
❹ The items

All primary foodstuffs 1961-2003: 120 product lines of FAO *Commodity Balances* (SUA)

gathered into 5 « compartments » of food biomasses

PLANTS (VEGE)

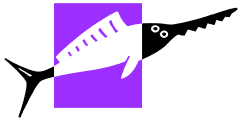
Cereals : wheat, rice, barley, maize…
Sugar crops : sugarcane, sugar beat…
Pulses : beans, peas…
Oilseeds : soybean, groundnut, coconut…
Roots & tubers : cassava, potato…
Fruits & vegetables : apple, onion…
Stimulants : cocoa, coffee, alcohol…



GRAZING ANIMALS (RUMI)
Meats : bovines, goat, mutton…
Milk, Butter, Animal fats…

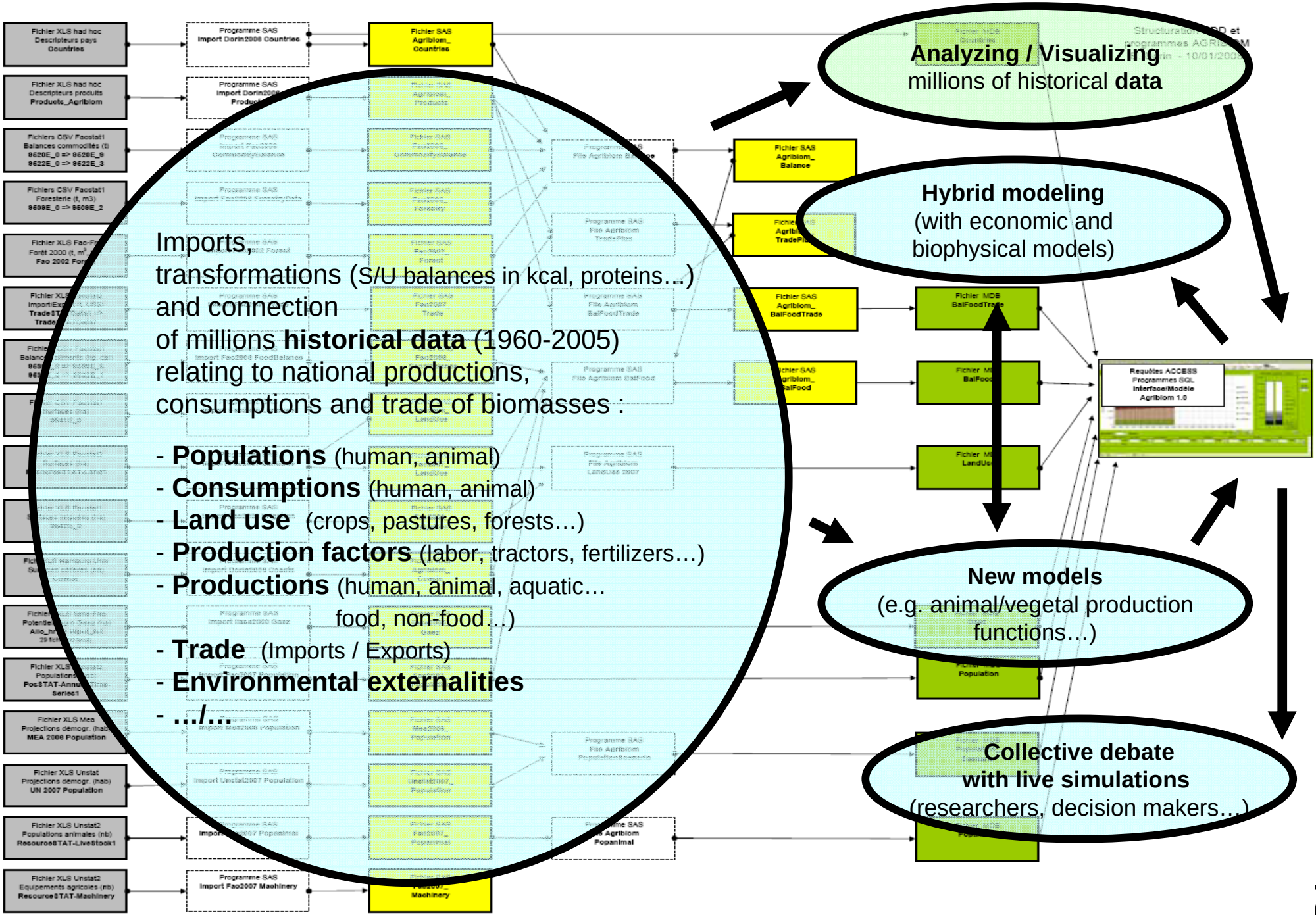
Non-GRAZING ANIMALS (MONO)
Meats : poultry, pig…
Eggs…

FRESH WATER (AQUA)
Fishes…



MARINE (MARI)
Demersal & Pelagic fishes… Fats…

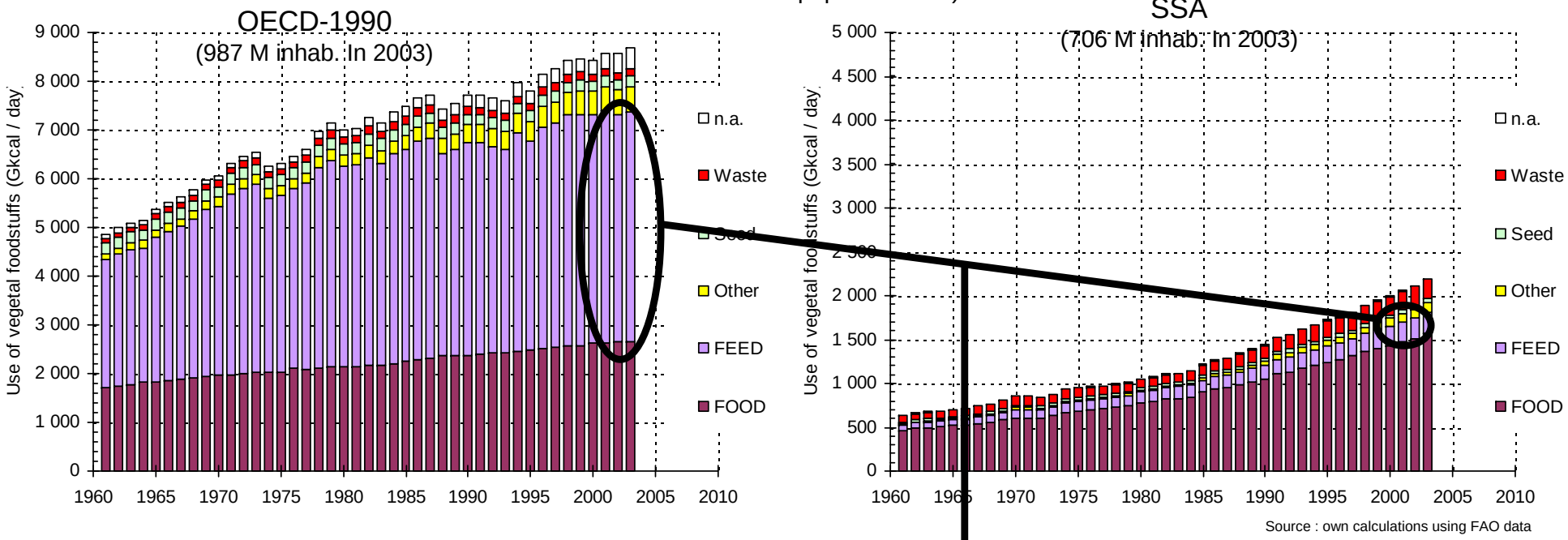
❺ An interactive interface



❻ A statistical model for livestock production

Facts

(in 2003, the OECD cattle ate 3 times as much food as the SSA human population did)



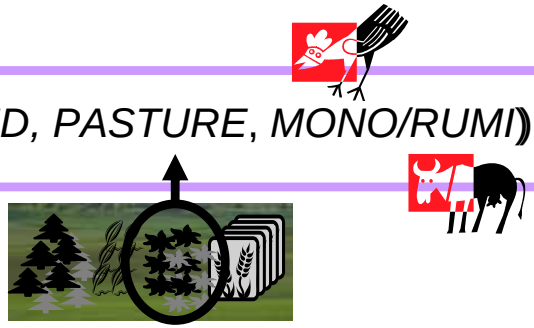
Model

(Dorin & Le Cotty)

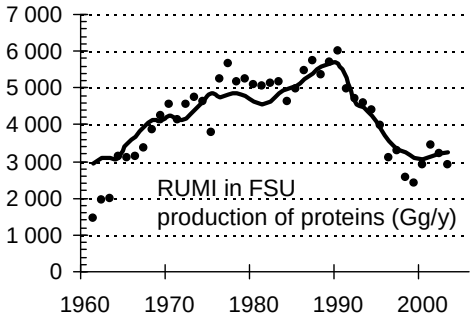
Cross-country animal production functions

RUMI production (meat & milk proteins)
MONO production (meat & eggs proteins)

= f (*FEED, PASTURE, MONO/RUMI*)



Results



=> replicate very-well the past 40-year of national/regional/global animal productions

=> “on-line” tests and modeling

(choice of model, change of parameters/coefficients, simulations…)

❼ Annual R/U balances of food biomass reconstituted (1961-2003) ...or simulated (2050)

Param | 06MEA | AgM_RZV_00 | 2050

		Population (Kcap)	Rations (kcal/j/cap)		FOOD (Gkcal/j)	FEED	VANA	SEED	WAST	Residu	UTIL Total (Gkcal/j)	Surfaces (Kha)		Rendement (kcal/j/ha)	PROD Production (Gkcal/j)		EXIM Exp - Import (Gkcal/j)	Delta
1	OCDE 1990	1 066 211	2500	3	2 666	4 314	329	165	414	390	8 279	495 000	400 000	23600	9 440		1 161	0
			6	0	6	0	0	0	0	0	6	95 000	160 183	40	6		0	0
			43	0	46	32	15	0	0	-12	81	3 295 546	981 321	82	80		0	0
			251	0	268	81	142	0	5	59	554		576 226			984	430	0
			200		213	0	1	5	3	-30	193					455	262	0
2	Afrique Sub-Saharienne	1 662 000	2500	3	4 155	0	0	90	224	4	4 473	338 000	299 000	12400	3 708		-765	0
			4	0	7	0	0	0	0	0	7	39 000	65 352	100	7		0	0
			17	0	28	1	0	0	0	0	29	2 359 453	86 980	340	30		0	0
			129	0	214	1	7	0	1	1	225		692 000			21	-203	0
			350		582	0	0	0	0	3	585					-1	-585	0
3	Ex-URSS	239 212	2500	3	598	3 586	184	90	230	-97	4 590	310 000	300 000	15300	4 590		0	0
			4	0	1	0	0	0	0	0	1	10 000	62 436	14,09	1		0	0
			33	0	8	2	0	0	0	-1	9	2 213 218	453 332	20	9		0	0
			251	0	60	34	21	0	1	-11	105		300 998			715	610	0
			212		51	0	0	0	0	-11	39					182	142	0
4	Asie	4 427 101	2500	3	11 068	1 939	596	298	744	232	14 877	559 000	539 000	27600	14 876		0	0
			12	0	53	0	5	0	0	-1	57	20 000	77 749	740	58		0	0
			76	0	336	32	3	0	0	-4	367	2 033 947	480 076	743	357		-11	0
			159	0	704	37	32	0	12	-34	751		512 000			401	-349	-1
			253		1 120	0	2	5	7	-20	1 114					528	-586	0
5	Amérique Latine	773 659	2500	3	1 934	3 386	248	124	310	197	6 200	310 000	250 000	24800	6 200		0	0
			3	0	2	0	0	0	0	0	2	60 000	26 431	90,222	2		0	0
			39	0	30	10	2	0	0	-7	35	2 039 563	283 809	161,427	46		11	0
			251	0	194	11	45	0	5	14	269		444 625			564	295	0
			207		160	0	0	2	3	-7	158					433	275	0
6	Moyen Orient et Afrique du Nor	631 964	2500	3	1 580	0	0	35	68	52	1 755	89 000	88 800	15300	1 359		-396	0
			4	0	3	0	0	0	0	0	3	200	14 757	150	2		0	0
			36	0	23	3	0	0	0	-1	25	1 136 711	69 672	350	24		0	0
			222	0	140	9	7	0	2	6	164		321 000			25	-139	0
			238		150	0	0	1	1	-1	151					-2	-154	0
	TOTAL Zone	8 800 147			22 000	13 225	1 358	802	2 010	778	40 173	2 101 000	1 876 800		40 173		0	0
					72	0	5	0	0	-1	76	224 200	426 910		76		0	0
					471	80	20	0	0	-25	546		2 355 190		546		0	0
					1 580	173	254	0	26	35	2 068	13 078 440	2 846 848			2 711	644	-1
					2 276	0	3	13	14	-67	2 239	2 002				1 595	-645	0

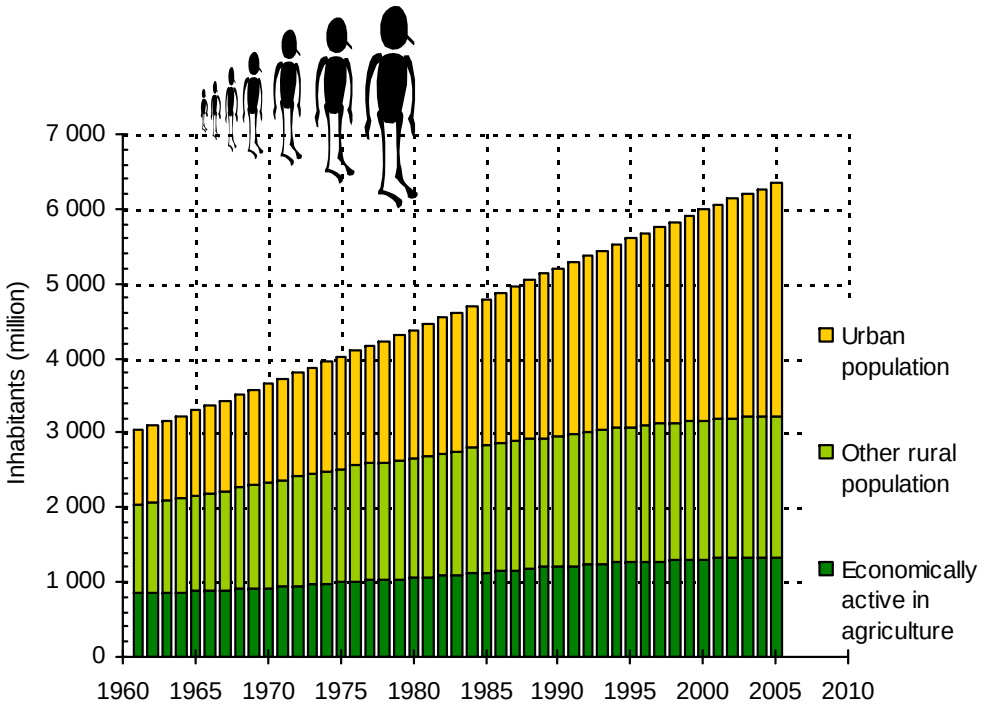
Part II

From past trends to scenarios

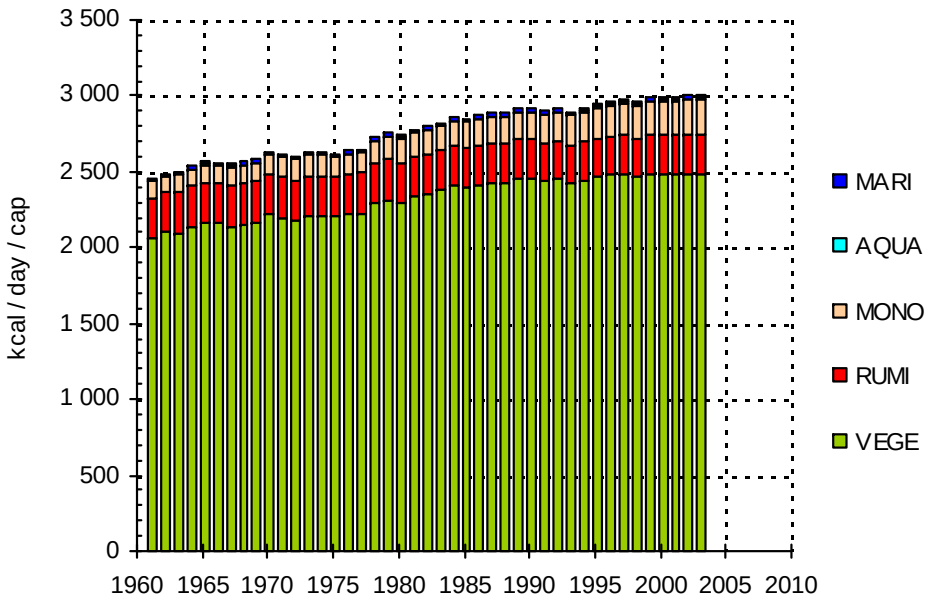
A 1961-2003 brief overview of the world food economy through Agribiom eyes…

❶ From average world increases…

- The population doubled



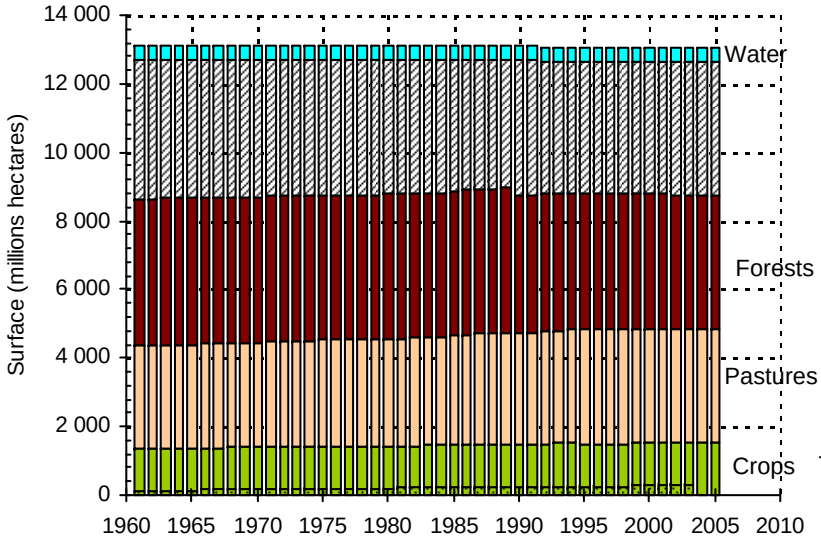
- The per-capita food availability increased too…



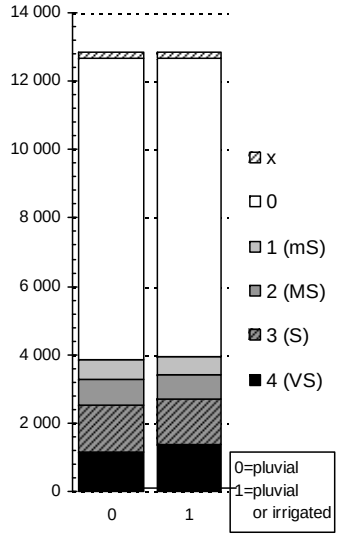
Source: own calculations using FAO data

On the resources side:

- Agricultural area ↗
  - Pastures : + 11%
  - Crops : + 13%

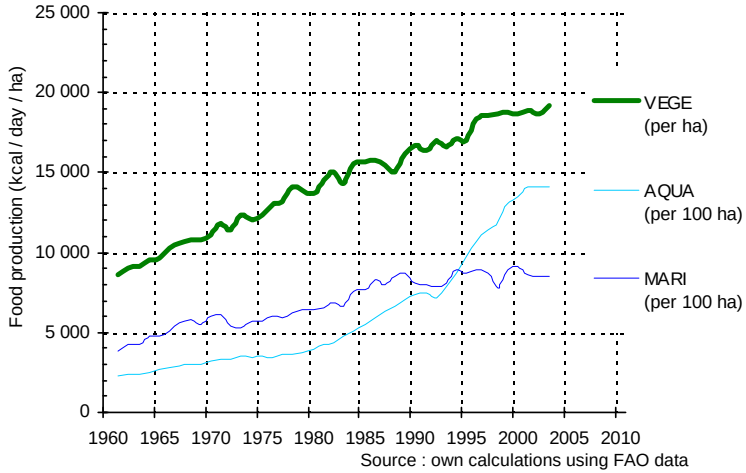


Up to (potential)



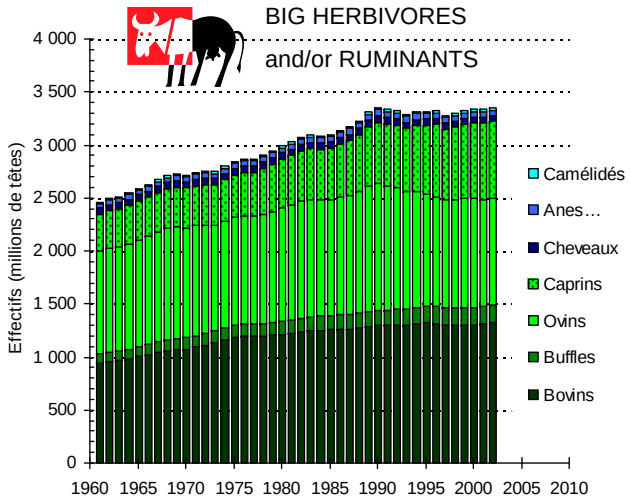
Source : data from Fischer *et al.*

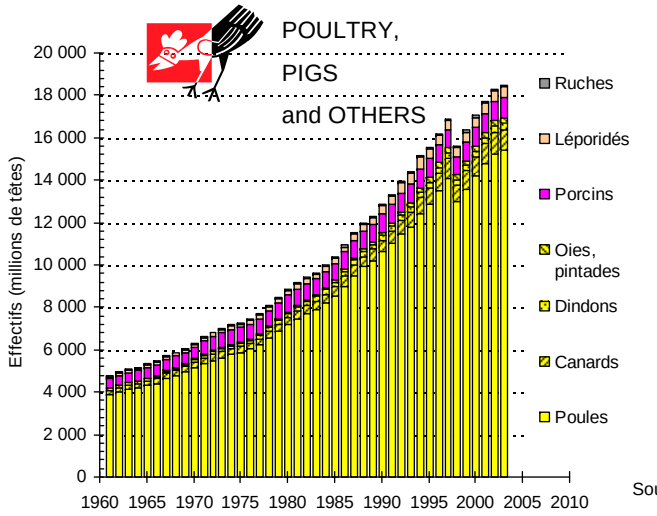
- Land and labour productivities ↗
  - Veg calories / cultivated ha : + 123%
  - Veg calories / farmer : + 53%



Source : own calculations using FAO data

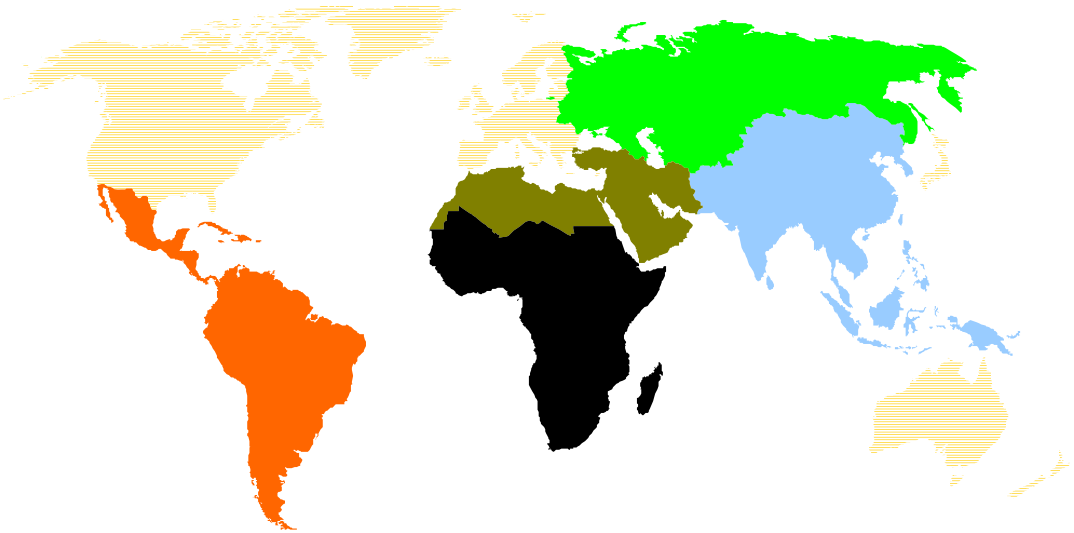
- Livestock ↗





Source : data from FAO

❷ ...to regional disparities

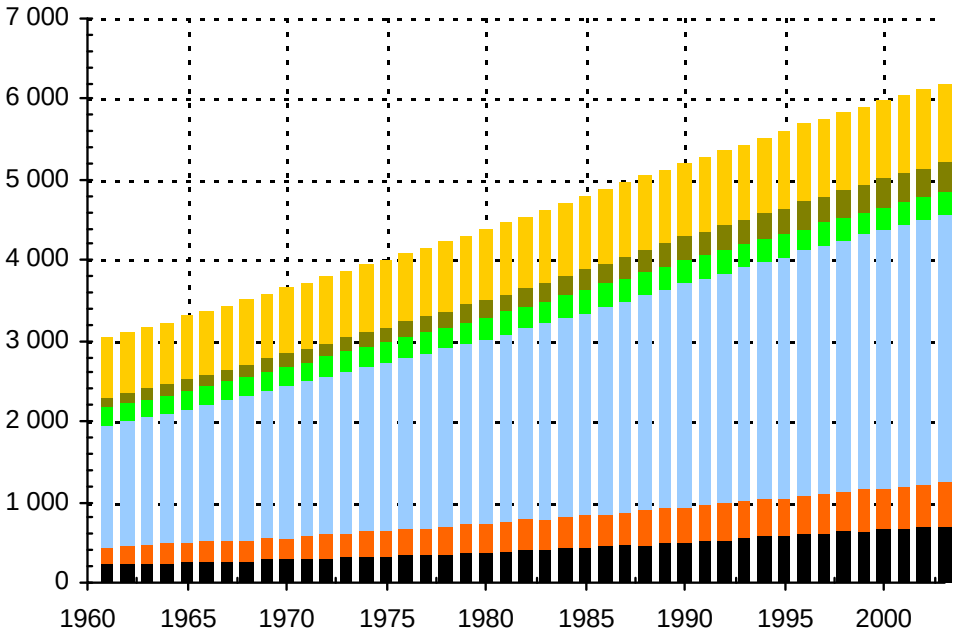


The 6 MEA regions

- OECD = Oecd-1990
- MENA = Middle East & North Africa
- FSU = Former USSR
- ASIA = Asia
- LAM = Latin America & the Caribbean
- SSA = Sub-Saharan Africa

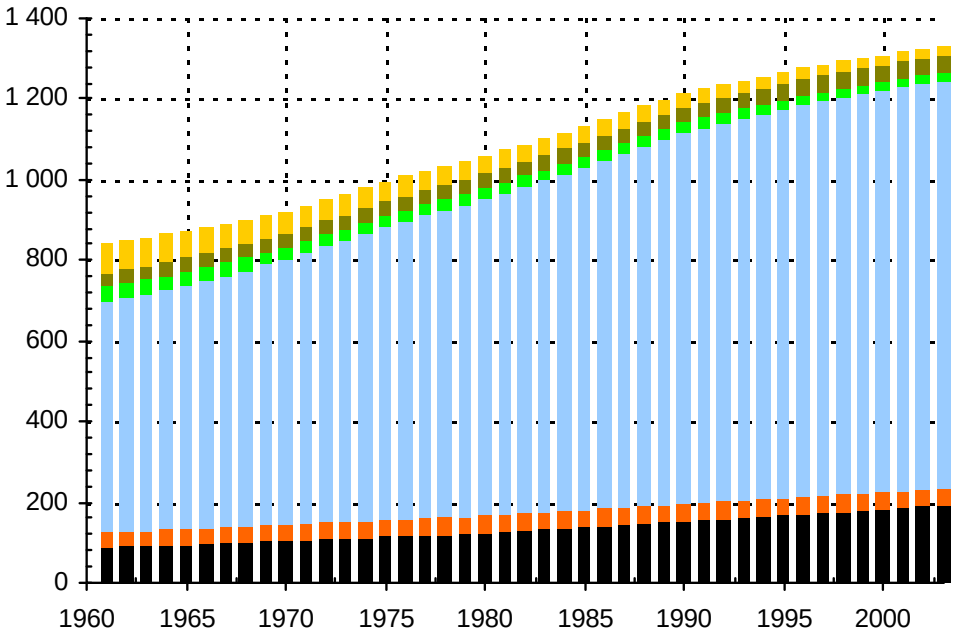
Human populations

Inhabitants (million)



Farmers : highly and increasingly concentrated in Asia and Africa

Active agricultural workers (million)

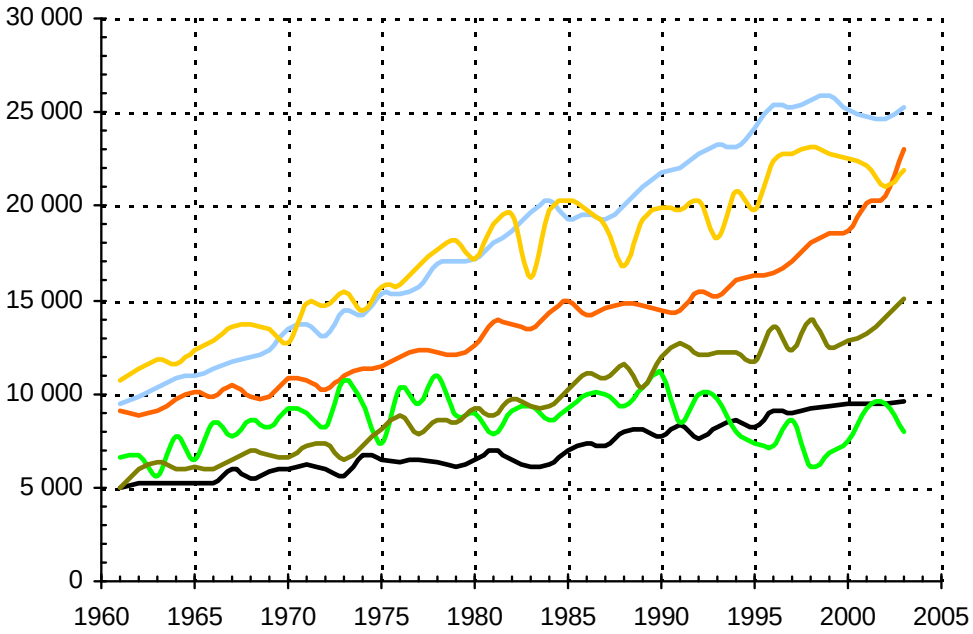


Source: data from FAO

Highest land productivity in ASIA

Note : 10 000 kcal =
~ 2.4 kg of soybean
~ 2.8 kg of rice milled
~ 2.9 kg of pea
~ 3.0 kg of wheat
~ 15.0 kg of potato
~ 58.8 kg of tomato

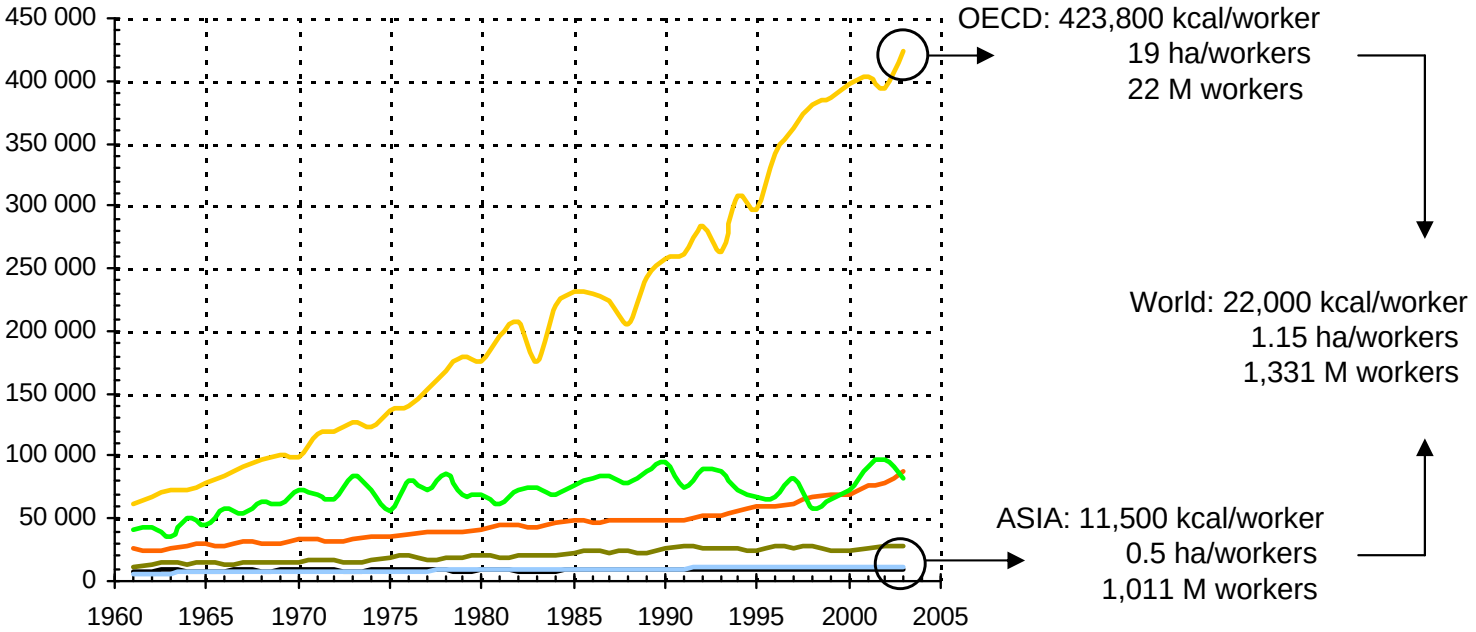
Vegetal kcal / day / cultivated hectare



Source: own calculations using FAO data

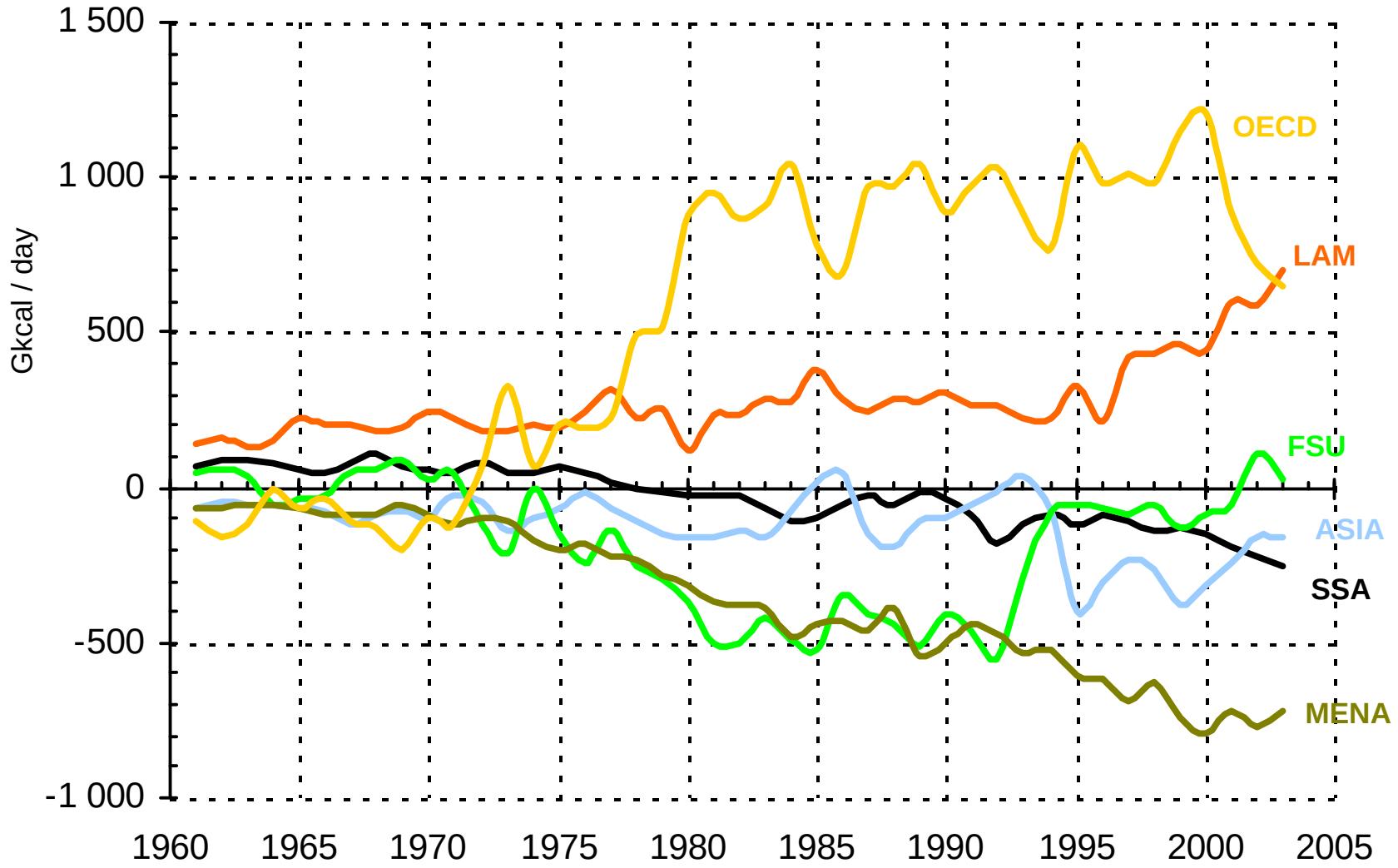
A labour productivity boom in OECD

Vegetal kcal / day / agricultural worker



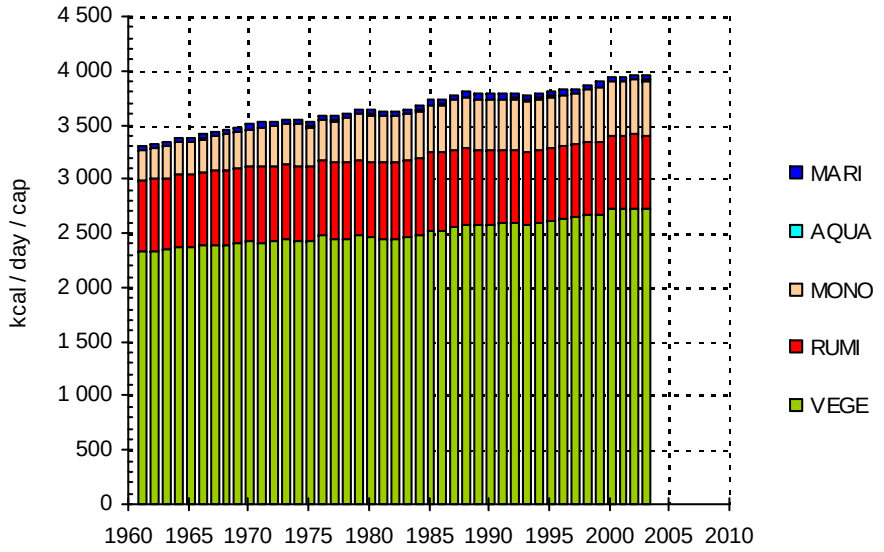
A boom of food trade to clear surpluses and fill in deficits

Net balance of vegetal food trade
(Exports – Imports)



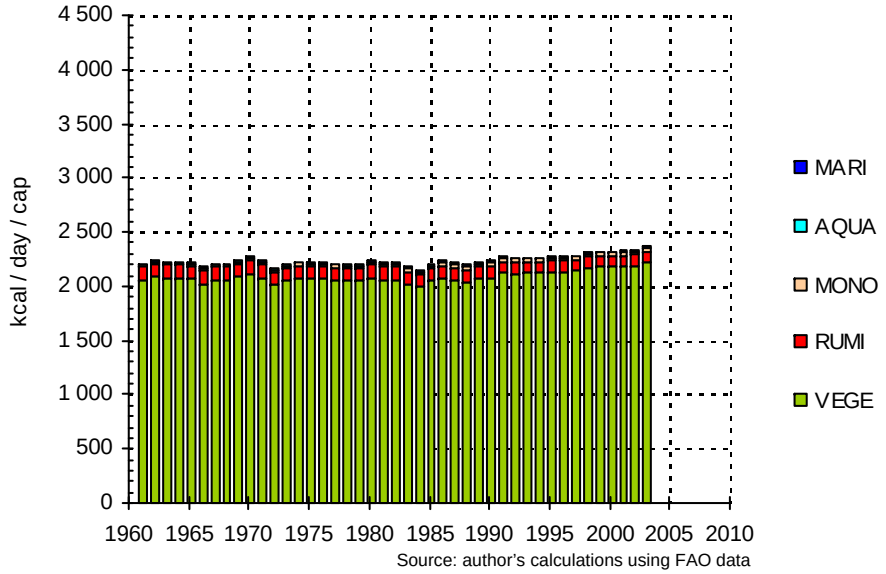
Source: own calculations using FAO data

But still very large disparities in per-capita food availabilities



OECD

- Animal proteins :
  71 g / day on 125 (60%)
- Animal fats :
  89 g / day on 165 (55%)



Source: author's calculations using FAO data

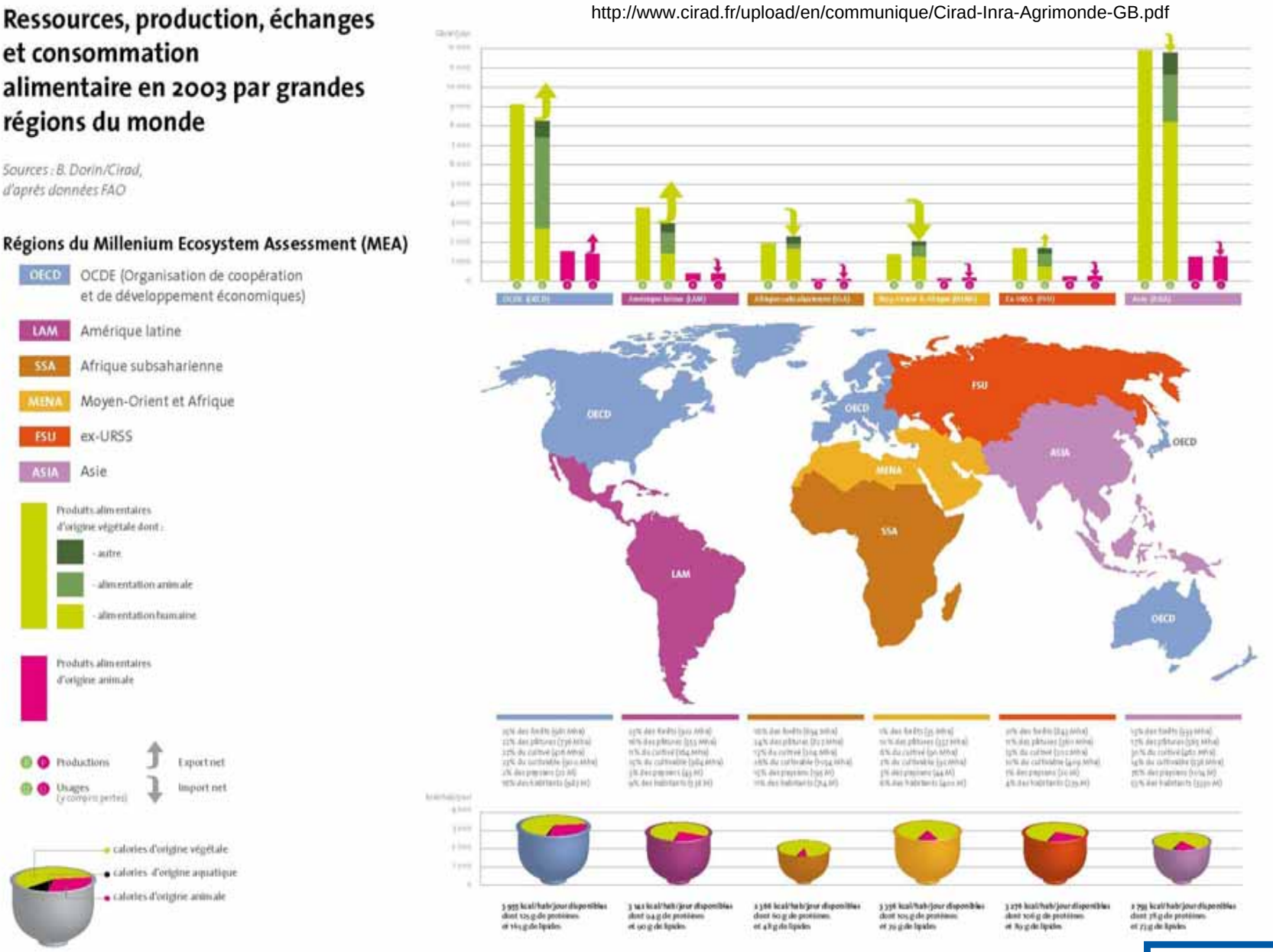
Sub-Saharan Africa

- Animal proteins :
  12 on 60 g / day (20%)
- Animal fats :
  10 on 48 g / jour (20%)

❸ Towards which new «equilibrium» in 2050 ?

- Resources, productions, trade and uses of food biomasses (2003)

http://www.cirad.fr/upload/en/communique/Cirad-Inra-Agrimonde-GB.pdf



- Scenarios, hypotheses, collective debates… (2050)

Agribiom simulations

Part III

Scenarios and challenges for feeding the world in 2050

First explorations by Agrimonde : the “AGO” and “AG1” worlds...

❶ Towards which new «equilibrium» in 2050 with...

- +/- population growth (7-11 billions inhabitants in 2050) ?
- +/- incomes, incomes distribution and population migrations (regional opportunities of decent incomes, self-subsistence…) ?
- +/- change in food diets (vegetal/animal, macro/micro nutrients…) ?
- +/- demand in non-food products (bio-energies, bio-materials...) ?
- +/- economic liberalization and trust in international trade (“sovereignty” in cereals / other basic vegetal foodstuffs / feed for animal productions / animal foodstuffs…) ?
- +/- environmental regulations (forests, greenhouse gases, biodiversity…) ?
- +/- important crisis on present yield boosts (fossil fuels, water, pesticides, phosphates…) ?
- +/- climate change
- …/…

❷ Building-principles of the scenarios

- 2 scenarios, 2050 timeline, MA regions
- Same regional population trends assumed in both scenarios

in order to assess each region's capacity to satisfy its food needs

⇒ trade is addressed only after this capacity is assessed,

without any market simulation

- Agrimonde 1 : a normative scenario: sustainable development is assumed to be met by 2050; the goal being to better understand the dilemmas, tensions, synergies and challenges of such a development
  - Drastic reduction of under-nourishment and also of excess of caloric intakes
  - Ecological intensification : agriculture meets growing needs, is a driving force of development, and respectful of the environment

- Agrimonde GO : a trend-based scenario, reprocessing Global Orchestration, the most efficient MA scenario, regarding poverty alleviation and under-nourishment reduction:
  - Fast technological advances and trade liberalization
  - Reactivity in ecosystem management

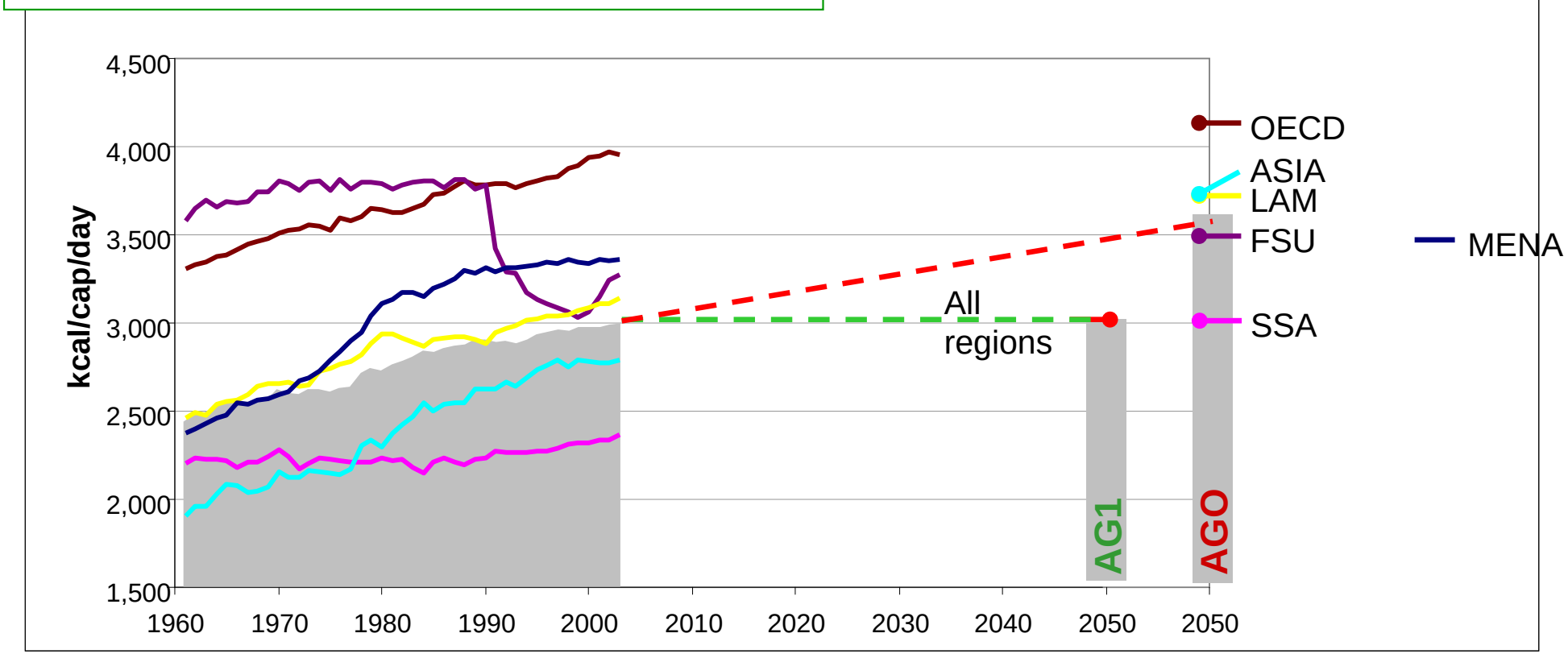
❸ Quantitative assumptions and resource-use balances

Quantitative assumptions : (1) regional uses

- Populations in 2050 : UN median projections
- Food consumptions (availabilities):

AG1: 3,000 in all regions;
2,500 of plant origin ; regional specificities in the allocation of the remainder

AGO: GO assumptions, growth explains consumption trends



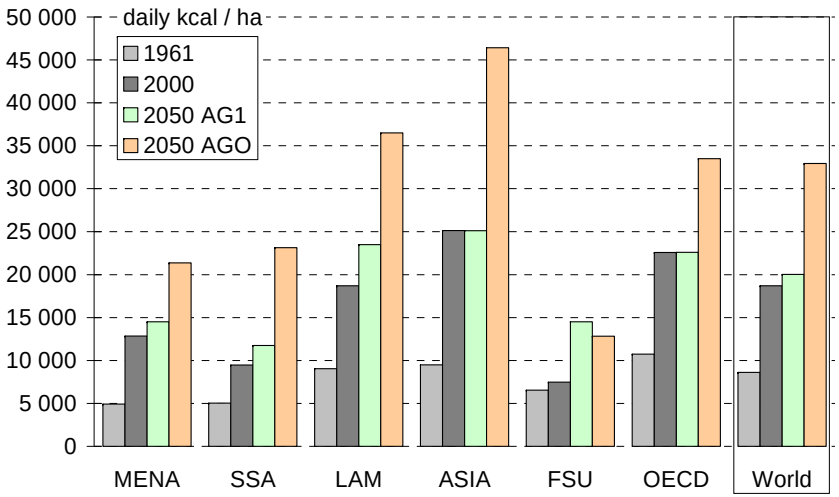
Quantitative assumptions: (2) Regional resources

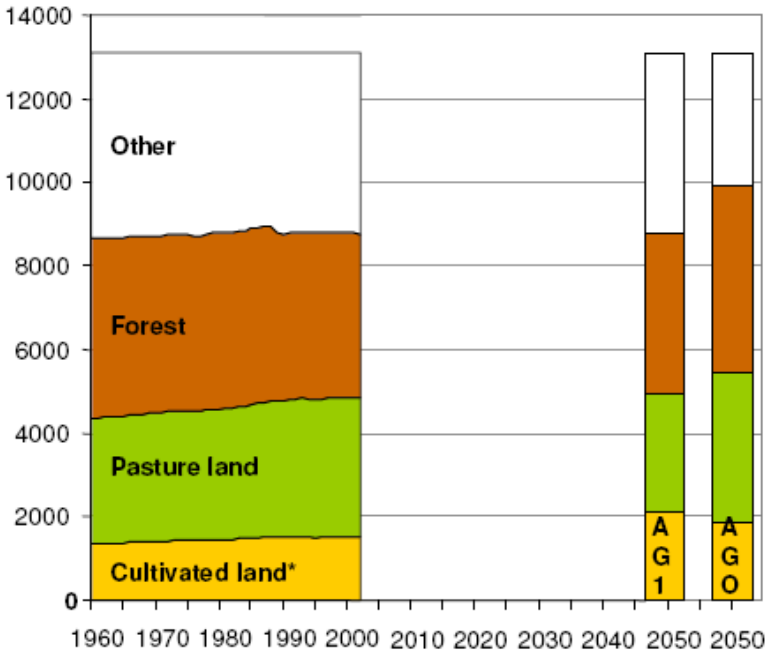
1. Plant: land use and foodcrop yield

- Agrimonde GO: **GO assumptions**
- Agrimonde 1: **What possible evolution of land use and yield ?**
  - given past trends
  - while preserving ecosystems and natural resources
  - given possible impacts of climate change

2. Animal: F (pasture area, feed, mono/rumi)

3. Aquatic: resource - use identity





Quantitative scenarios (2000-2050)

		World	AGO	AG1
Use		Population	+47%	
Use	Consumption	Kcal/cap/day	+20%	stable
Use	Consumption	Animal share	from 16% to 23%	stable
Resource	Land use	Cultivated land 1961-2000 :+4 M ha per year	+ 23% + 7 M ha per year	+ 39% +12 M ha per year
Resource	Land use		11% non food	
Resource	Land use	Forest	stable	
Resource	Land use	Pasture	+7%	-15%
Resource		Yield 1961-2000 : +2% per year	+ 75% +1,14% per year	+7% +0,14% per year

Resource-use balances in 2050

- **In both scenarios, at the global level, resources meet needs in 2050**
  - – But 3 regions remain net importers of food calories : SSA, MENA, ASIA
  - – Net deficits/surpluses of food calories considerably increases between 2000 and 2050
- **Regional net deficits and surpluses are higher in AG1**

Main conclusions

The planet can feed properly 9 billion people in 2050 but it will depend on…

- **What is on our plates** which is a key driver for:
  - Preserving ecosystem services
  - Saving farming inputs
  - Solving nutrition-related health problems
  - Opening new opportunities for non-food use…

  what is lost before & after reaching our plates

Diets (and waste) are key determinants of resource-use balances

World	AGO 2050	AG1 2050
Food consumption per cap. & per day	+ 20%	stable
Animal share	23%	stable (15%)
Total use of plant cal. (Gkcal/day) (28,100 in 2000)	53,600 (+90%)	37,600 (+35%)

- **Food trade**

  can secure regional food needs since:
  - natural resources are not distributed like human population
  - and agriculture development takes time

  providing that:
  - local opportunities of wealth creation are developed
  - as well as a fair and secure trade regulation system coupled with environmental regulation

Spatial organisation, technological innovation & social change are strongly related

- AGO and AG1 relate to 2 contrasted yield-surface trade-offs and have different consequences on ecosystem preservation
- AGO can be seen as a possible sustainable option since cultivated areas are limited thanks to high yields
- AG1 is another sustainable option, providing:
  - The development of radical innovations in farming systems to overcome biodiversity loss and GHG emissions associated with a large land conversion
  - A change in performance criteria of farming systems
  - A blurring of the frontiers between urban areas, agricultural areas and areas of nature

To follow up...

- Need to discuss and investigate scenarios
  at different geographical scales
  with various stakeholders (to share & debate different visions of the future)

- Need to extend/link simulations with
  - price/market mechanisms
  - induced consumptions of fossil fuel and water
  - GHG emissions/sinks (C, CO_2, CH_4, N_2O…)
  - regional employments / incomes / migrations
  - …biodiversity

- Need to involve a large set of stakeholders
  and academic disciplines into food production,
  food security, food safety and food quality issues

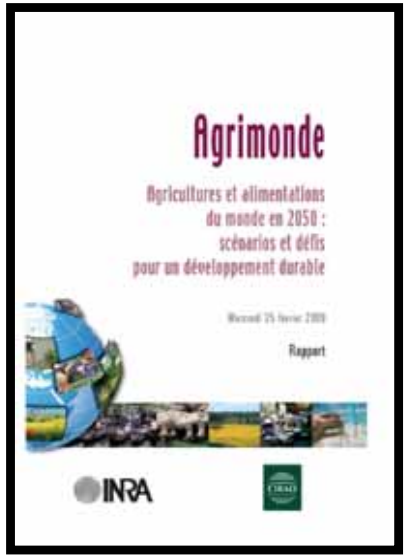
Agrimonde materials available on the web & elsewhere

http://www.inra.fr/l_institut/prospective/agrimonde
http://www.cirad.fr/actualites/toutes-les-actualites/articles/2009/science/resultats-de-la-prospective-agrimonde

Preliminary results
8 pages brochure
May 2008

FR & EN

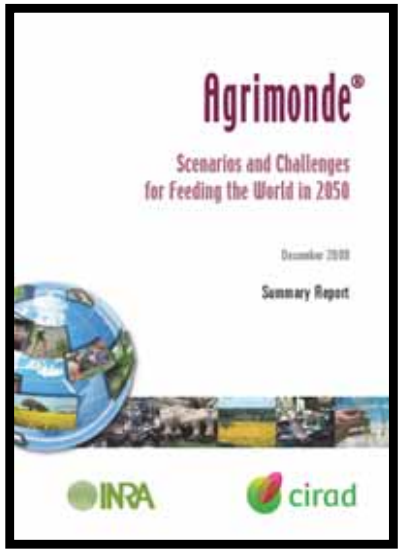
REPORT
200 pages
Feb. 2009



Coming soon…

BOOKS (FR & EN)
2010

SUMMARY REPORT
32 pages
June 2009



FR & EN
Updated versions
December 2009

BROCHURE
12 pages
Oct 2009

FR & EN

VIDEOS
Presentations & debates
Feb-Oct 2009

FR only

Thank you for your attention

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